

AUV Navigation and Platform Development

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LONG-TERM GOALS

The long term goal for the navigation component of this work is to further the technology of autonomous underwater systems for ocean survey and minefield reconnaissance / mapping / neutralization. We wish to address the implementation and enhancement issues associated with applying advanced processing algorithms to a low-cost computing platform to provide a synergistic navigation solution given the size, power and cost constraints of small AUVs.

The goal for the platform development component of this work is to provide next generation ultra modular mass produced mini AUV platforms for current and future sensor development and deployment.

OBJECTIVES

This particular project is aimed at improvements to low cost navigation systems using COTS equipment and extended Kalman filtering with sensor bias learning and compensation. Other related

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work includes the study of autonomous fault detection and compensation, as well as sea state learning for use in motion planning and oceanographic survey.

The platform development objectives are 1) improved navigation and positioning capabilities using enhanced asynchronous Kalman filters together with fibre-optic gyros; 2) miniaturized body shape for optimizing launching and recovery operations; 3) docking and recharge mechanisms to support extended mission operations; 4) LBL position sensor for extended underwater navigation; 5) DVL for current profiling and bottom; 6) high-frequency side-scan sonar for bathymetry characterization; 7) phased array scanning sonar for low-resolution bathymetry and obstacle avoidance purposes.

APPROACH

The FAU and NPS investigators have, using one of the FAU Ocean Explorer AUVs, conducted a series of survey runs designed to characterize the errors produced in navigation with dead reckoning. The system employs a triaxial magnetometer for compass heading, an Acoustic Doppler Velocity Log to measure speed over the ground and water column. In theory, with perfect measurement, the velocities rotated into navigation coordinates may be integrated on-line to provide the vehicle with knowledge of its position. Experimental results, however, indicated that the heading bias, based on low-cost COTS magnetometer, is the most dominant source of error found in inertial navigation. With sensor errors these systems degrade and to achieve a one percent of distance travelled error compass heading should be accurate to within a degree. The errors in compass heading are critical to precision in navigation of these small vehicles, so there is a need to both compensate for these errors before missions, and to on-line fuse independent position measurements, such as DGPS / LBL / USBL sensors.

The new mini AUV has been designed to minimize integration, reconfiguration, maintenance and operations costs. Structurally the Mini AUV is composed of 12 inch long modular molded plastic. These sections can serve either as dry pressure vessels or as faired flooded or pressure compensated sections. The plastic is a high strength micro glass fiber reinforced resin called Ultem. It has 70% of the strength of aluminum but 50% of the weight. By using plastic the maintenance problems of corrosion and ground faults are minimized. A unique cabling system that runs along faired channels on the outside of the sections allows easy interchange of the order of the sections without having to open or rewire any of the sections. This design uses the same LONTalk based distributed control system as the OEX so only one power and network cable is needed for most of the sensors and actuators and likewise many of the electronic components are easily transferred to the new design. This vehicle will use rechargeable Lithium ION batteries with over twice the volumetric energy density of the OEX's NiCad batteries.

The interior cross section is an 8.5 inch rounded octagon. This provides flat sides top and bottom for easy mounting of sensors, actuators, and electronics. The cross section size was selected after reviewing the size requirements of existing and planned electronics and sensor systems. The 8 inch size was selected as the smallest size that still easily accommodates a significant majority of components. Thus a minimal configuration would weight less than 100 lbs and could be deployed by one person. The standard tail section is a cross configuration of rudder and sternplane with a single thruster. However the ultra modular design allows for custom tail sections. Moreover, cross body thruster sections are easily accommodated. Custom configuration of the vehicle is accomplished by adding or rearranging the plastic sections. Because of the small cross section even long configurations

of say 10 ft. still require no more operations support than the OEX. For example, for the same length vehicle the Mini AUV's displacement is less than 1/6 that of the ocean explorer.

WORK COMPLETED

Experimental results for a variety of runs have been obtained. Compass bias has been learned and precompensated using a 'deviation table'. Inside a small AUV, the effect of local magnetic anomaly on the magnetometer can be significant. Figure 1 shows a typical deviation table where the horizontal axis represents the compass output. It should be noted that the first and second harmonic relationship are shaped by the presence of hard-iron and soft-iron respectively, as suggested by the technical support of the compass vendor. A peak-to-peak error of 10 degrees is not uncommon, and the problem is complicated by an additional variability due to currents in nearby power cables. To further reduce the heading bias, we have developed an extended Kalman filter which identifies the residual bias in a compensated system. Current findings, however, suggest that the residual bias is non-stationary. That is, it varies with true heading in a more or less periodic fashion.

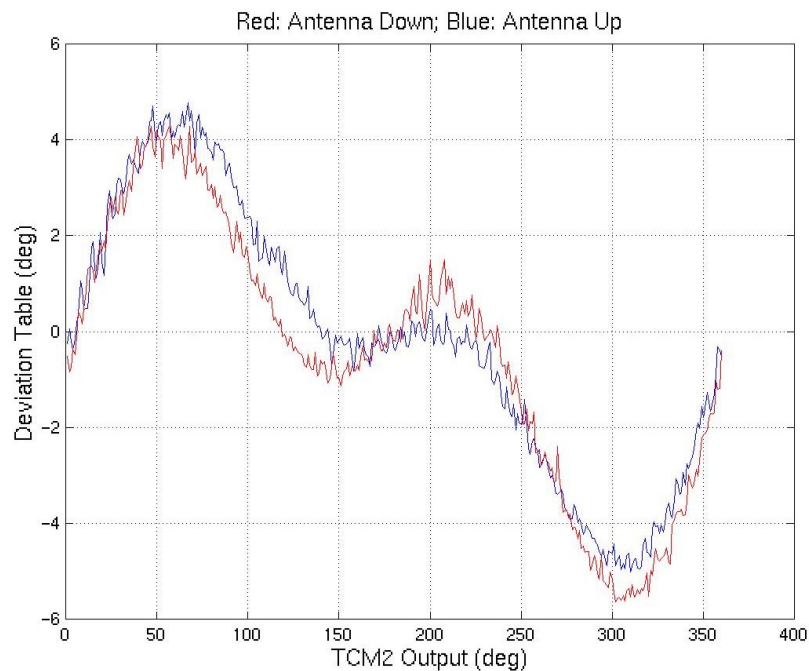


Figure 1: A typical deviation table for OEX

This year, a new system has been devised in which occasional surfacing is suggested to take Differential GPS fixes. Bias correction from a single fix is possible. Using a few single fixes, path errors are bounded, and for the results obtained, times between successive fixes lie between 75 and 400 seconds.

A summary of the average time between fixes is a function of the error covariance (converted to standard deviation) as given in the Figure 2.

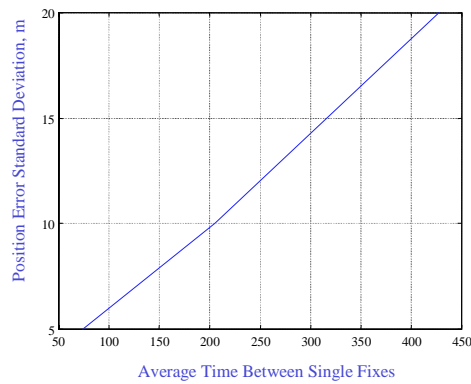


Figure 2: Time between fixes vs. position error standard deviation

The mini –AUV injection and extrusion molds are completed. The mold maker was 6 months late in delivering the molds. Final form fit and function testing is underway and pressure testing is scheduled for next month. The internal components and packaging design is complete. The DVLs and CTD have been ordered. The core LonTalk module called the high performance standard node has been completed and dozens built. Porting of the software to QNX and PC-104 is well underway. It is expected that the first mini-AUV will be finished by year end.



IMPACT/APPLICATION

Navigation of underwater platforms is critical to survey and mapping work. Low cost systems are also essential to the Navy's future. While precision navigation may be solved for large submarines, low cost units for small AUVs will have to rely on less accurate sensors and ways of fusing information from a variety of sources to maximize the achievable accuracy will be important.

Low cost expendable mass produced AUVs are needed elements in the Navy's goal of clandestine remote mine reconnaissance operations in shallow water. The new mini-AUV is the first AUV designed specifically to address these needs. It is expected that that the ultra modularity will serve as a multiplier in enabling further development of AUV systems, sensors, and operational capabilities.

TRANSITIONS

This work transition into Ocean Sampling Systems using low cost AUVs, and to Models for VSW Minefield Simulation technology.

RELATED PROJECTS

The navigation work is leveraged from ONR funded work in Fault detection and Compensation, and from ONR work funding the Modeling and Simulation of Multi Robot Systems performance in UXO clearance.

Sampling and Survey with AUVs in Adverse Weather Conditions, ONR.

AUV Navigation and Platform Development, ONR.

Remote Sampling and Survey of Shallow Water Using AUVs with Application to Mine Reconnaissance, ONR.

Acoustic Communications with AUVs and Autonomous Oceanographic Sampling Network Development. ONR

ACOMS Acoustic Communication between UUV and Submarine, ONR ATD.
AUV Hydrodynamics in Shallow Water during Adverse Weather Conditions, ONR

Coordination of Experiments Using AUVs at the SFTF, ONR
ONR MURI on Nonlinear Control

USF Projects, CoBop, UK Autosub, WHOI Remus, MIT Odyssey

Advanced Machinery Control Architecture (ACMA) Laboratory Development for Automated Navy Ship Auxiliary System Control, Reconfiguration and Failure Recovery, ONR.

Dependable Network Topologies with Network Fragment Healing for Component Level Intelligent Distributed Control Systems for Naval Shipboard Automation, ONR.

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